PATENT SPECIFICATION

825,900

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COMPLETE SPECIFICATION

DRAWINGS ATTACHED

Improvements in or relating to a Method of Interconnecting an Aluminium Terminal Member to an Aluminium Capacitor Foil Member

We, GENERAL MOTORS CORPORATION, a Company incorporated under the laws of the State of Delaware in the United States of America, of Grand Boulevard in the City of Detroit, State of Michigan in the United States of America (Assignees of JAMES LLOYD HANCOCK and LEE J. LAKES) do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method of interconnecting an aluminium terminal member to an aluminium capacitor foil member.

The invention involves the use of an aluminium capacitor foil member having a thickness less than .001 inches, preferably between .0008 and .00017 inches, and comprises forming a brittle good dielectric oxide layer over the natural oxide layer on, at least, one of the members, juxtaposing the members with the brittle oxide layer between the members and then subjecting the members to pressure at a series of discrete areas so as to disrupt the oxide layers, and cold pressure weld the members together.

Since the good dielectric oxide layer is brittle, it bares when it is disrupted by the pressure, discrete areas of the interfacial surfaces between the foil member and terminal member to enable the members to be cold pressure welded.

The brittle good dielectric layer is preferably on the capacitor foil member. It then serves three functions: first as a dielectric; second to bare the interfacial surfaces for cold pressure welding; and third to impart strength to the thin capacitor foil member.

Oxide layers having the desired qualities are formed by electrolysis, the suitable electrolytes being ammonium borate and an acid, or an alkali metal borate and an acid.

The scope of the invention is defined by the accompanying claims; and how it may be performed is hereinafter particularly described with reference to the accompanying drawings in which:

Figure 1 is a perspective view of an aluminium capacitor foil member and an aluminium terminal member joined according to the present invention;

Figure 2 is a perspective view of an aluminium capacitor foil member and an aluminium terminal member joined according to the invention;

Figure 3 is an enlarged cross-section through the terminal member and foil member of Figure 2 before they were joined;

Figure 4 is another enlarged cross-section through the terminal member and foil member of Figure 2 and illustrates what occurs on joining;

Figure 5 is an enlarged cross-section through the terminal member and foil member after they have been joined.

A capacitor aluminium foil member 10 less than .001 inches thick and preferably between 0.0008 and .00017 inches thick is shown in Figure 1 covered with a brittle high density electrolytically formed dielectric layer 12 of aluminium oxide. An aluminium terminal member 14 also covered with a brittle high density dielectric layer 16 of aluminium oxide has been joined to the foil member 10 by the method according to this invention, the layer 16 being on the terminal member surface joined to the foil member.

Figure 2 shows an aluminium capacitor foil member 20 less than .001 inches thick and preferably between 0.008 and 0.00017 inches thick to which an aluminium terminal member 22 has been joined according to the present invention. The surface of the terminal member 22 to be joined to the foil member was covered, before it was joined to the foil

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member, by an electrolytically deposited layer 24 of brittle high density aluminium oxide, but the corresponding surface of the foil, unlike the foil in Figure 1, was not.

Figure 3 illustrates on an enlarged scale the layers of material on the terminal member 22 and foil member 20, shown in Figure 2, shortly before they were joined.

The aluminium terminal member 22 has naturally formed oxide layers 32 and 34 on opposite surfaces, the layer 34 being covered with a brittle high density dielectric film 24. The foil member 20 is covered only with a naturally formed oxide layer 30, 31.

Figure 4 shows how, and what, occurs when the terminal member 22 and foil member 20 of Figure 2 are joined. A tool 40 having a head 46 with a plurality of closely adjacent square projections 44 is forced against the foil member 20 at a pressure such that each projection exerts a pressure on the foil member 20 of about 50 lbs. per square inch at a series of discrete areas; the pressure should not, however, be so great that the projections 44 puncture or tear the foil member 20. The projections 44 apply localised pressure at a series of discrete areas to the layer of material such that the layer 24 is disrupted as shown by the arrows in Figure 4. The terminal member is engaged by a reaction element 42. When the layer is disrupted it bares of oxide the areas of the interfacial surfaces of foil member and terminal member subject to the localised pressure applied by the projections 44. Opposing areas 60 (Fig. 5) cleaned thereby are then cold pressure welded together. Thus the areas of the terminal member and foil member to be welded together are cleaned and welded substantially simultaneously by one operation of the tool 40.

Figure 5 is a fragmentary view on an enlarged scale of the join between the terminal member 22 and foil member 20 effected by the application of localized high pressure as just described.

The naturally formed layers 30 and 34 and the electrolytically deposited layer 24 have been removed from areas 60, by the disruption of the layer 24 effected by the tool 40, the areas 60 being cold pressure welded together. Separating the areas 60 are pockets 50, which are filled with particles from the naturally formed layers 30 and 34 and from the disrupted layer 24. The welds in the areas 60 result in good mechanical strength and high electrical conductivity between the terminal member 22 and foil member 20. Thus in the method according to the invention the naturally formed oxide layers 30 and 31 on the foil 20 and the layers 32 and 34 on the terminal member 22 are not, as has been conventional, removed by abrasive or chemical cleaning. In practice the electrolytically formed layer 24 of aluminium oxide is often on the foil member, and the terminal member has only a naturally formed layer.

There are three main kinds of oxide layer which can be formed on aluminium. First, there is the natural oxide layer which forms instantaneously on aluminium when it is exposed to air. This oxide layer generally prevents good electrical conductivity and a secure mechanical bond between a foil member and a terminal member. The layers 30, 31, 32 and 34 in Figures 3, 4 and 5 of the drawings consist of such natural oxide, which is exceedingly thin and highly refractive, has very poor dielectric characteristics, and is usually contaminated with impurities of aluminium such as iron, silicon, copper, magnesium, manganese, titanium and gallium as well as dirt.

The other two kinds of oxide layer are artificially formed, usually on top of the natural layer. One kind is thicker (about .0001 inches) than the natural layer but porous, and can be formed, for example, by conventional anodic oxidation using sulphuric, oxalic or chromic acid as an electrolyte; alternatively it can be formed by a simple immersion treatment in an oxidizing solution such as a hot solution of sodium carbonate containing potassium dichromate. Oxide layers formed by these methods do not form brittle good dielectric layers, and are not used in the method of this invention.

The third kind of layer forms a good dense brittle dielectric layer, and is therefore the one used in the present invention as the layer 24. The layer 24 is preferably formed by anodic oxidation using sodium borate ($Na_2B_4O_7$) and boric acid, or phosphoric acid, or an equivalent acid as the electrolyte. Phosphoric acid alone results in a porous type dielectric layer but when used with sodium borate, potassium borate, or ammonium borate, or similar borate compounds results in a dense good dielectric layer. A layer formed using, as electrolyte, a solution of 10% boric acid (H_3BO_3) together with one of more of its salts is dense, impermeable to the solution and practically insoluble in it. The thickness of the layer is usually such as to provide poor protection against corrosion and abrasion but excellent dielectric properties because of its high density. When the solution contains sodium borate, usually supplied as $Na_2B_4O_7.10H_2O$, it may advantageously constitute 1% of the total weight of the solution. The higher the voltage used, the greater the resistivity of the solution should be and consequently the smaller the percentage of sodium borate used. When high voltages are used, a straight boric acid solution with no sodium borate may be preferable. Purity of materials in the solution is important, distilled water being necessary, and exclusion of chlorides most important. Ammonium borate may advantageously be

used instead of sodium borate when high voltages are employed.

During the electrolysis a film of gelatinous or colloidal aluminium hydroxide is first formed on the aluminium, and is then converted into a dense layer of aluminium oxide. The presence of chlorides in the solution is adverse to the formation of the gelatinous or colloidal aluminium hydroxide film. On the other hand, the introduction of colloids like glue, gums, and so on, is beneficial as they are apt to strengthen the colloidal aluminium hydroxide layer. The high-density dielectric layer left is material alumina (aluminium oxide—Al_2O_3) that is visibly present, has a very high dielectric constant, and contains very little physically absorbed water. Molecular arrangement of this high density film is such that it is a very good dielectric.

In order to show the effectiveness of the method according to the invention, two series of tests were conducted in which different methods of attaching aluminium terminal members to a aluminium foil members were used.

In the first series of tests foil members less than .001 inches thick and too thin to withstand cleaning by etching or abrasives were used.

In the first test of one series the terminal member was folded into engagement with an uncleaned foil member as though a capacitor foil member were being wrapped to form a capacitor with a terminal member connected thereto. No pressure was applied to connect the terminal member and foil member across the fold, the terminal member and foil member being therefore not connected mechanically. The average resistance of ten readings in ohms was .00870.

In the second test an uncleaned aluminium foil member and terminal member were stitched together at a pressure of 2560 *p.s.i.* The average resistance of ten readings was .00554 ohms. The average resistance of .00554 ohms is appreciably less than .00870 ohms average in the first test so that better electrical conductivity resulted from the stitching. However, stitching perforates the materials and therefore weakens the mechanical strength of the terminal member and foil member at the join.

In the third test an artificial layer of brittle good dielectric aluminium oxide was formed on both the foil and terminal and the terminal member and foil were then stitched together at a pressure of 2560 *p.s.i.* The average resistance of ten readings was .0697 ohms. The layer has thus adversely affected the electrical conductivity as compared with the first two tests. Again the mechanical strength of the foil member and terminal member at the join is not good because of the stitching.

In the fourth test the terminal member and foil member were joined by the method of the present invention described above.

The average resistance of ten readings was .00295 ohms, which is considerably less than in any of the previous tests. Moreover the mechanical strength of the join between the terminal member and foil member is superior to that obtained with the old methods. There was no tearing or disintegrating of the foil members or terminal members due to stitching, chemical etching or mechanical abrasive cleaning or brushing. There was no haste to join the terminal member to the foil member so as to avoid natural oxidation of the aluminium.

In the second series of tests foil members having a thickness capable of withstanding cleaning by etching or abrasives was used but less than .001 inches thick, and tools of the type shown in Figure 4 were used for effecting the join between the terminal members and foil members.

In the first test of the second series uncleaned terminal member and an unclean foil member were joined. This join had very poor mechanical strength.

In the second test an abrasively cleaned terminal member was joined to an abrasively cleaned foil member. There was again a join having little mechanical strength in spite of the fact that the cleaning was accomplished within about five seconds of the application of pressure by the tool 40.

In the third test the terminal member and foil member were joined by the method according to the invention in which both the foil member and film member had an artificially formed brittle good dielectric aluminium oxide film. The mechanical strength of the joint was excellent.

In the fourth test only the terminal member had an artificially formed brittle good dielectric oxide layer—that is as described with reference to Figures 2 to 5. An excellent mechanical joint was again obtained.

In all the tests of the second series the electrical connection was excellent, the joint having an infinitely low resistance.

WHAT WE CLAIM IS:—

1. A method of interconnecting an aluminium terminal member to an aluminium capacitor foil member having a thickness less than .001 inches, which comprises forming a brittle good dielectric oxide layer over the natural oxide layer on at least one of the members, juxtaposing the members with the brittle oxide layer between the members and then subjecting the members to pressure at a series of discrete areas so as to disrupt the oxide layers, and cold pressure weld the members together.

2. A method of interconnecting an aluminium terminal member to an aluminium capacitor foil member having a thickness between .0008 and .00017 inches, which comprises forming a brittle good dielectric oxide

layer over the natural oxide layer on at least one of the members, juxtaposing the members with the brittle oxide layer between the members and then subjecting the members to pressure at a series of discrete areas so as to disrupt the oxide layers, and cold pressure weld the members together.

3. A method of interconnecting an aluminium terminal member to an aluminium capacitor foil member having a thickness between .0008 and .00017 inches, which comprises forming a brittle good dielectric oxide layer over the natural oxide layer on the aluminium foil member, juxtaposing the members with the brittle oxide layer between the members and then subjecting the members to pressure at a series of discrete areas so as to disrupt the oxide layers and cold pressure weld the members together.

4. A method according to any of the preceding claims in which the brittle oxide layer is formed by electrolysis, the electrolyte being an alkali metal borate and an acid.

5. A method according to any of claims 1 to 3 in which the brittle oxide layer is formed by electrolysis, the electrolyte being ammonium borate and an acid.

6. A method according to claim 4 or 5 in which the acid is boric acid or phosphoric acid.

7. A method according to any of the preceding claims in which the members are subjected to pressure by means of a tool having a plurality of closely adjacent projections.

8. A method of interconnecting an aluminium terminal member to an aluminium capacitor foil member having a thickness between .0008 and .00017 inches substantially as hereinbefore particularly described with reference to Figure 1 of the accompanying drawings.

9. A method of interconnecting an aluminium terminal member to an aluminium capacitor foil member having a thickness between .0008 and .00017 inches substantially as hereinbefore particularly described with reference to Figures 2 to 5 of the accompanying drawings.

10. A capacitor in which an aluminium terminal member and an aluminium foil member are interconnected by a method according to any of the preceding claims.

E. WILLIAMSON

Chartered Patent Agent

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825,900 COMPLETE SPECIFICATION
1 SHEET

This drawing is a reproduction of the Original on a reduced scale.

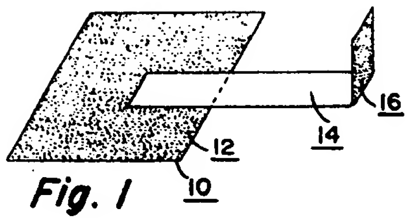

Fig. 1

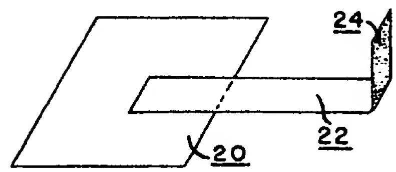

Fig. 2

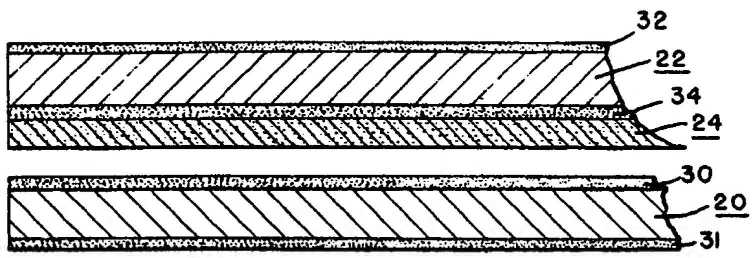

Fig. 3

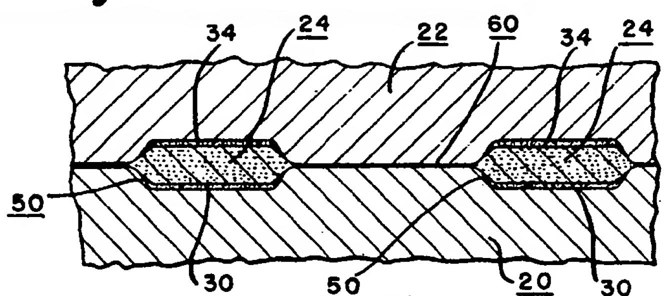

Fig. 5

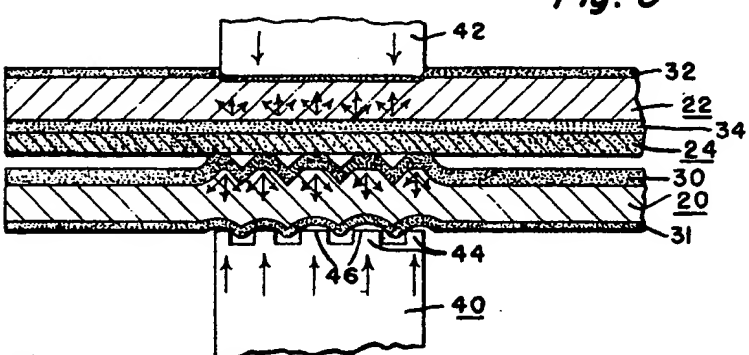

Fig. 4